ARO 23235.1-GS-H

(2)

Diagnostic Study of Atmosphere-Terrain Interaction Leading to the Formation of Dust Clouds and Poor Visibilities Over Near East Desert Areas

Final Report

Authors

Lonzy J. Lewis
Pieter J. Feteris (deceased)

30 June 1989

U.S. Army Research Office

Grant Number
DAAG29-85-G-0116

Department of Physics and Atmospheric Sciences
Jackson State University
Jackson, MS 39217

Approved For Public Release;
Distribution Unlimited.

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE Unclassified	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) DAAG 29-85-G-0116	5. MONITORING ORGANIZATION REPORT NUMBER(S) ARO 23235.1-GS-H
6a. NAME OF PERFORMING ORGANIZATION Dept. of Physics and Atmospheric Sciences 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION U. S. Army Research Office
6c. ADDRESS (City, State, and ZIP Code) Jackson State University 1400 J. R. Lynch Street, P. O. Box 17660 Jackson, MS 39217	7b. ADDRESS (City, State, and ZIP Code) P. O. Box 12211 Research Triangle Park, NC 27709-2211
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U. S. Army Research Office 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAG29-85-G-0116
8c. ADDRESS (City, State, and ZIP Code) P. O. Box 12211 Research Triangle Park, NC 27709-2211	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)
Diagnostic Study of Atmosphere-Terrain Interaction Leading to the Formation of Dust Clouds and Poor Visibilities over Near East Desert Areas

12. PERSONAL AUTHOR(S)
Lonzy J. Lewis, Pieter J. Feteris (deceased)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 9/1/85 TO 2/29/88	30 June 1989	20

16. SUPPLEMENTARY NOTATION
The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A comparison of the frequency of occurrence of poor visibilities in areas and during periods of intense agricultural, industrial and military activity with that in sparsely populated areas unaffected by war and military manoeuvres, has been undertaken. Three years of surface reports from 850 stations in the Near East and adjacent North Africa were screened for visibilities coded as 90 through 95 and 9 through 10 on FIGGE and NCC data bank tapes.

Seasonal maps of the location of stations reporting poor visibilities, a calendar of poor visibility for each station and maps of the distribution of those stations reporting fog/rain, fog/snow/drifting snow and sand/dust were prepared for most of the three year period. Only the most reliable and important results are shown. In mountainous regions poor visibilities occurred frequently all year round. Low frequencies of poor visibility reports were found in Eastern Tunesia, Western Lybia, West Africa and the Sudan. (It must be remembered that during World War II the desert battle between the British and the German

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

armies in North Africa caused noticeable deterioration of visibility in Western Egypt.) It is recommended that this climatology be completed.

1. Preface

The work reported here is almost entirely that of the late Prof. Pieter J. Feteris, who died in October 1986. All of the findings and conclusions are his. My contribution to this project has been mainly reserved to the writing of the final report and handling the closing phase of the project.

Special thanks to Dr. Walter Saucier, Senior Atmospheric Scientist A.R.O., Dr. Lewis Berkofsky, Blaustein Institute for Desert Research, and Ben Gurion University of the Negev, Israel, for guidance during the initial stages of this Project and to Mr. Paul Mulder and Mr. Gregg Walters for assistance in writing the programs for retrieval of data from the NAVY SPOT and NMC ADP archives at the Scientific Computing Division of the National Center for Atmospheric Research in Boulder, Colorado. Mrs. Debra Jackson typed the manuscript.

2. Table of Contents

3. List of Illustrations and Tables

4. Statement of the Problem

Preliminary Climatology of Poor Visibilities over the Near East and Adjacent Mediterranean and North Africa

4.a Introduction

The ingredients for poor visibilities in dry air are wind and a source of dust which is free to blow: There are two kinds of blowing dust; namely, natural blowing dust and man-made blowing dust. Both affect visibility and certain types of remote sensing and communications in an adverse way. In moist air, the ingredients are fog droplets forming on natural aersols and smog caused by chemical interactions among industrial effluents and water vapor.

Natural dust caused by flow over loose fine-grained soil can be divided into several catogories according to flow type (Wigner and Peterson, 1982).

a) dust devils (limited areal extent and occurrence)

b) thunderstorm outflow (duration up to 30 minutes)

c) frontal passage (several hours in advance of a cold front and approximately an hour after passage of a cold front (haboobs))

d) trough-induced (4 to 8 hours in duration)

e) associated with deep cyclones (12-36 hours in duration)

Man-made dust may be generated in several ways. Ploughs, trucks, tractors, military vehicles and bulldozers moving over silt and clay may cause dust in any type of weather except rain. The removal of this dust is mainly by horizontal flow. If the winds are weak at all levels, day-time convection will only cause the fine clay particles to be redistributed in the vertical. The concentration of this man-made dust in the lowest 100 feet would decrease during the day-time as the silt particles are spread over a deep layer (Berkofski 1982). At night and under stable conditions most of the

generated dust will remain confined to a rather shallow layer and continue to accumulate as military or industrial activity goes on. Hence, heavy vehicular traffic over fine soil would cause prolonged periods of poor visibility in a stagnant air mass with only shallow day-time convection and during cyclogenetic activity with winds of over 40 kt over silty soil. In the latter case enormous amounts of particles are lifted into the troppsphere and transported thousands of kilomters away from their source (Brandli et al., 1977).

Poor visibilities not caused by dust can be attributed to fog and classified as radiation fog, advection fog, or smog (smoke plus fog). Radiation fogs occur in any region where a shallow layer of moist stagnant air is capped by dry air. Such areas can be over and near marshy terrain, close to bodies of warm water and where convective day-time rains have fallen and sufficiently moistened the soil. Advection fogs are found in low-lying coastal areas adjacent to cool sea surfaces over which moist, warm air is slowly moving or where any air has stagnated long enough to become super-saturated. Smogs are encountered downwind of industrial areas. They occur when the rate of input of aerosols, produced by industrial processes, fuel combustion and solid waste disposal, exceeds the rate of removal by the wind.

4.b The Approach

While naturally occuring fog and dust can <u>in principle</u> be monitored and predicted when terrain, vegetation, soil structure, airflow, surface temperature and moisture are known, fog and dust produced by human activities, such as transportation, inadvertent explosions or leakage of effluents and military activity, cannot be predicted on the basis of historical data and are mainly estimated on the basis of numerical simulations and diffusion models. However, in the past, cattle-marketing, ploughing and harvesting in semi-arid regions has taken place at regular and somewhat predictable

intervals, battles have been fought, industry has been developed. It is quite conceivable that in some regions and during some periods these activities occurred on a scale large enough to cause local anomalies in the climatic trend and oscillation of visibility and aerosol concentrations in the lower atmosphere. An example are the five to tenfold increases of the frequency of occurrence of visibilities below 700 meters reported in Burg el Arab in the Western desert of Egypt during 1941 and 1942 when the North African desert war between the British and German Armies was waged in full force (El Fandy, 1953). The problem at hand is to separate temporary anomalies in the frequency of poor visibility occurrence from the climatological background and to link these anomalies to human activities. Whatever these human activities are, they always produce a source of pollutants. Hence local aerosol concentration in populated areas will frequently be the result of a balance between source input and removal by ventilation and increase with decreasing windspeed. Downwind from the source horizontal advection causes deterioration of visibility when the wind blows from a certain direction while the correlation between visibility and wind speed decreases with distance.

Fogs tend to form over water surfaces, moist soil and swampy terrain when the windspeeds are low and the relative humidities are high. Here human activity can only enhance fog formulation when the input consists of hygroscopic nuclei. In these areas industrial effluents are more likely to have an effect on visibility than traffic, military activity or cultivation.

Fog is frequent over mountain slopes and mountain tops when low level air is forced upwards by strong winds to heights above its condensation level. It is doubtful whether human activities in these areas have any significant effect on visibility. Therefore one would expect visibilities in sparsely

populated areas, unaffected by war or military manoeuvres, to correlate well with windspeeds and that a certain range of visibility would occur regularly in certain atmospheric circulation systems. In cultivated areas or regions frequently visited by war or military manoeuvres, one would expect anomalies that may correlate fairly well with windspeeds and often also with wind direction during limited periods. Stations located in those regions may show conspicuous differences in visibility from that reported by their nearest neighbors. Near cities, the frequency of poor visibility may show a steady upward trend which is interrupted only by initiation or suspension of large scale industrial activity. To separate these cases of human deterioration of visibility from the climatological background over the desert areas of North Africa and the Middle East is a formidable task, particularly when the war years of the 20th century have to be included. Hence this effort should be preceded by a pilot study that must clearly show the feasibility of such a endeavor. If, indeed, the suggested separation is feasible, a next study would be the exploration of terrain and soil type and the history and social geography of areas in which conspicuous visibility anomalies occur.

The combined results of these studies may then be used to verify and/or adjust the results obtained by simulation of aerosol generation and removal that are to be applied over similar terrain where no historical data exist.

4.c Data Collection and Analysis

The minimum requirements for a historical data base on which a meaningful climatology can be based has been set at five consecutive years of measurement. Data reports of visibilities below 2 miles (surface synoptic code number 90-95 and 1-10) by stations in the Near East had to be selected from the FIGGE and NCC data banks at the National Climatological Center in Asheville, N.C.

These reports were to be printed in full, thus showing associated meteorological variables for future reference. Attempts to perform this task at Jackson State University failed due to inadequate computer facilities for this particular task. It was then decided to obtain this information directly on microfiche from the National Center for Atmospheric Research in Boulder, Colorado. Due to the high cost of the endeavor and the extra man-hours required, three years instead of five years of surface data were ordered. The retrieval method that had to be applied automatically provided additional data from North Africa. Hence, the final set of data consisted of surface reports from 850 stations at which the visibility was coded as 90 through 95 and 9 through 10. The area was confined by the longitude circles of 20°W and 40°W and latitude circles of 10°N and 40°N. The time period was 1 January 1977 through 31 December 1979. Further processing of the data had to be done by hand.

The occurrence of poor visibility were tabulated for each station as shown in figure 1. Space was left on the tally sheets for adding information about geographical and topographical features.

Contingency tables were drafted for future use when stations with anomalies would have to be compared with the climatological background of the surrounding area.

Maps were prepared for the location of all stations reporting poor visibilities during the periods: (1) January through April (wet in the north, dry in the South), (2) May through September (dry north, wet South), and (3) October through December (generally dry everywhere). An example of such a map is shown in figure 2. Maps were also prepared for the location of stations reporting poor visibilities associated with fog and rain, snow and drifting snow, and that due to sand and duststorms or dust.

On a seventh map, stations reporting more than 120 cases of poor visibility over 365 days (40 cases in 120 days per map) were marked by a circle, stations

reporting less than 10 occurrences (4 cases per map) were marked by a cross.

To detect anomalous concentrations of days with poor visibility during periods of suspected ploughing and harvesting or periods of increased military activity and the like, calendars were prepared for each station. On these calendars days with poor visibility were plotted in different color codes for each of the years 1977-1979. An example is shown in figure 3.

4.d Summary of the most important results

The following results are preliminary and should be interpreted with caution. Figures 4 and 5 and Table 1 show analyses for the year 1977. Figure 4 shows the areas in which poor visibility was reported at least once per season. In the blank areas stations did not report visibility during one or more seasons. This does not necessarily mean that poor visibility did not occur in those areas. As more data is incorporated in the analysis adjustments will be applied and categorical statements will be re-expressed in terms of probability and statistics. The other figures are self explanatory.

Tentatively one can say that along coasts and in the mountains of Spain, the Elbrus and the Hindu Kush South of 40^{o}N, poor visibilities are, perhaps, equally likely all year round. Low frequencies of poor visibility are found in Eastern Tunesia, Western Lybia, West Africa and the Sudan. Elsewhere high and low frequencies seem to be intermingled. Completion of proposed five year climatology may provide a statistically more stable background for comparison with suspected anomalies.

Table 1 shows percentage frequency distributions for stations reporting poor visibility during a given number of days during 1977. Generally the percentage of stations reporting poor visibility on more than 60 out of 365 days is smaller than 2, although one station in Block 37 reported poor visibility during 240 days. The distributions of poor visibility occurrence are L-shaped

on block 60 and block 62 where roughly 85% of the stations report poor visibility on less than 20 days. Frequency distribution of duration (number of consecutive hours of poor visibility) have been prepared for only a few of these stations. Freuqncy distributions for block 8 and block 38 which are mountianous and for block 61, in which silt flats are located, are more flat (that of block 38 may be even bi-modal). Block 40 which provides the most reliable statistics in partly flat, partly silty and partly mountainous.

4.e Recommendations

It is recommended that a five-year climatology be done so that more reliable background statistics can be produced in the proper form. Also proposed are comparison with the climatology for the period 10 August-11 September 1983, for which U.S. plans for manoeuvres in the area were publicized, and for periods of intense Iran-Iraqui battles in Mesopotamia. There exists a catalog of atmospheric circulation types and topographical and geological maps for the Near East and adjacent areas which may be used for the investigation of meteorology and soil conditions in regions where there is a conspicuous local increase in the number of poor visibility record.

5. List of publications and technical reports.

None

6. List of participating scientific personnel and advanced degrees earned by them while employed on the project.

Not applicable to Jackson State University's Physics and Atmospheric Sciences Department

7. List of students employed

Name	Major	Classification
Rakesh Arya	Computer Science	Graduate
Joseph Demoulin	Meteorology	Undergraduate
Chukwubudem Ecijofor	Bus. Management	Undergraduate
Uri Hannon	Computer Science	Graduate
Sadie Jordan	Industrial Technology	Undergraduate
Benedict Nwokolo	Industrial Technology	Graduate
Rita Nwokolo	Social Science	Graduate
Godwin Okafor	Bus. Management	Graduate
Augustine Onyeka	Bus. Management	Graduate
Wendell Pickens	Meteorology	Undergraduate
Dwight Stuart	Computer Science	Graduate
Patrick Walker	Meteorology	Undergraduate

8. Bibliography

Berkofski, L., 1982: A Heuristic Investigation to Evaluate the Feasibility of Developing a Desert Dust Prediction Model. Monthly Weather Review 110, p. 2055-2062.

Brandli, H. W., J. P. Ashman and D. L. Reinke, 1977: Texas Dust Blows into Florida. Monthly Weather Review 104, pp. 1068-1070.

El Fandi, M. G., 1953: On the Physics of Dusty Atmospheres. Quart J. Royal Met. Society, 19, p. 284-287.

Wigner, K. A. and R. E. Peterson, 1982: Duststorms over Texas. Preprints 2nd Symposium on the Composition of the Non-Urban Troposphere, May 25-28, Williamsburg, Virginia.

Table 1 Percentage of stations reporting poor visibility on a given number of days in 1977. Blocks with less than 45 reporting stations have been omitted

Block No.	Number of Stations	Days with poor visibility reported at least once by a station							
		None	1-10	11-20	21-30	31-40	41-50	50	Maximum # of days
8	48	2.0	31.3	37.5	10.5	8.3	4.2	6.0	90
38	59	0	25.4	22.0	20.3	27.0	0	5.2	57
40	352	4.2	56.4	34.9	2.6	1.4	0.5	0	42
60	85	10.0	64.7	11.7	9.4	3.5	0.9	0	41
61	64	7.8	40.0	32.8	10.9	4.7	1.5	1.5	55
62	49	2.0	77.5	16.7	2.0	2.0	0	0	33

Figure 1 Worksheet for evaluation of poor visibilities and concurrent soil and weather conditions.

DUST EVALUATION PROJECT A.R.O.

39 1

BLOCK 61 STATION NUMBER 224 ELEVATION LAT 16.3 LON -0.1

SIZE: (Metropolis, medium size town, village or hamlet) ....

SOIL STRUCTURE:(rock, sand, silt,marshland etc)..

TOPOGRAHY: (valley, river, coastal,mountain, mountain slope, plain)............

....

CONTINGENCY TABLE FOR WINDSPEED-VISIBILITY RELATIONSHIP

Windspeed:	0-9 knots	10-19 knots	20-30 knots	over 30 knots	TOTALS
POOR VISIBILY	17	22	4	1	44
GOOD VISIBILY					
TOTALS					

Days and hours of poor visibility

77012812	5	14	18	3	7	3	1014.7	25	9
77012818	3	8	12	3	7	3	1011.0	28	8
77012900	0	[illegible]	6	3	5	3	1013.3	22	5
77012906	0	14	6	3	5	3	1013.3	17	4
77012912	0	18	10	3	5	4	1012.6	27	8
77012918	0	18	6	3	3	4	1010.6	27	5
77013000	0	0	0	3	5	4	1012.2	19	6
77013006	0	0	0	8	5	4	1012.2	15	3
77013012	0	12	12	3	5	4	1012.7	28	10
77013018	0	16	6	3	5	4	1010.7	25	12
77013100	0	0	0	8	5	4	1012.6	21	9
77013106	0	6	6	10	5	4	1012.4	17	5
77013112	0	8	6	6	5	4	1012.5	29	11
77013118	0	36	6	8	5	4	1010.0	29	[illegible]
77020100	0	6	4	8	5	4	1011.2	21	8
77020103	3	0	0	8	5	4	1010.7	18	8
77020212	0	4	18	10	7	0	1010.4	27	3
77020312	0	8	14	3	7	4	1014.4	27	4
77020318	9	8	23	1	7	4	1013.0	23	5
77020400	0	6	10	1	7	4	1015.6	23	4
77020406	0	4	8	3	5	4	1015.8	16	0
77020515	3	8	16	10	7	0	1013.7	30	
77020518	0	8	12	10	7	0	1014.1	28	6
7702[illegible]	0	5	10	8	1	7	1015.7	[illegible]	5

YY Mo DA TM	N	DD	FF	VV	WW	W	PPP	TT
77030212	0	6	24	5	7	4	1013.7	31
77030300	0	6	6	10	6	0	1015.0	24
77030306	0	6	16	6	7	0	1015.8	21
77030312	8	8	16	8	30	3	1016.8	29
77030612	0	6	18	10	7	0	1018.3	29
77031612	8	8	26	6	32	3	1011.9	34
77031815	0	8	8	6	31	3	1009.4	34
77040106	6	2	17	6	31	3	1013.5	21
77040112	9	2	23	1	31	3	1014.9	25
7704018	4	4	14	2	70	7	1012.8	27
77040200	6	34	14	4	32	4	1014.6	22
77040218	0	4	8	8	7	4	1009.4	29
77040300	6	0	[illegible]	10	6	1	1012.3	22
77040412	0	18	12	8	7	2	1009.4	35
77041918	9	34	19	3	32	3	1004.9	36
77042000	3	34	8	10	7	0	1007.3	31
77042200	9	2	39	1	31	3	1009.5	32
77042318	7	4	10	10	7	2	1004.3	39
7704[illegible]	[illegible]	[illegible]	10	8	7	1	1005.6	36

Figure 2 Working map for a particular season.

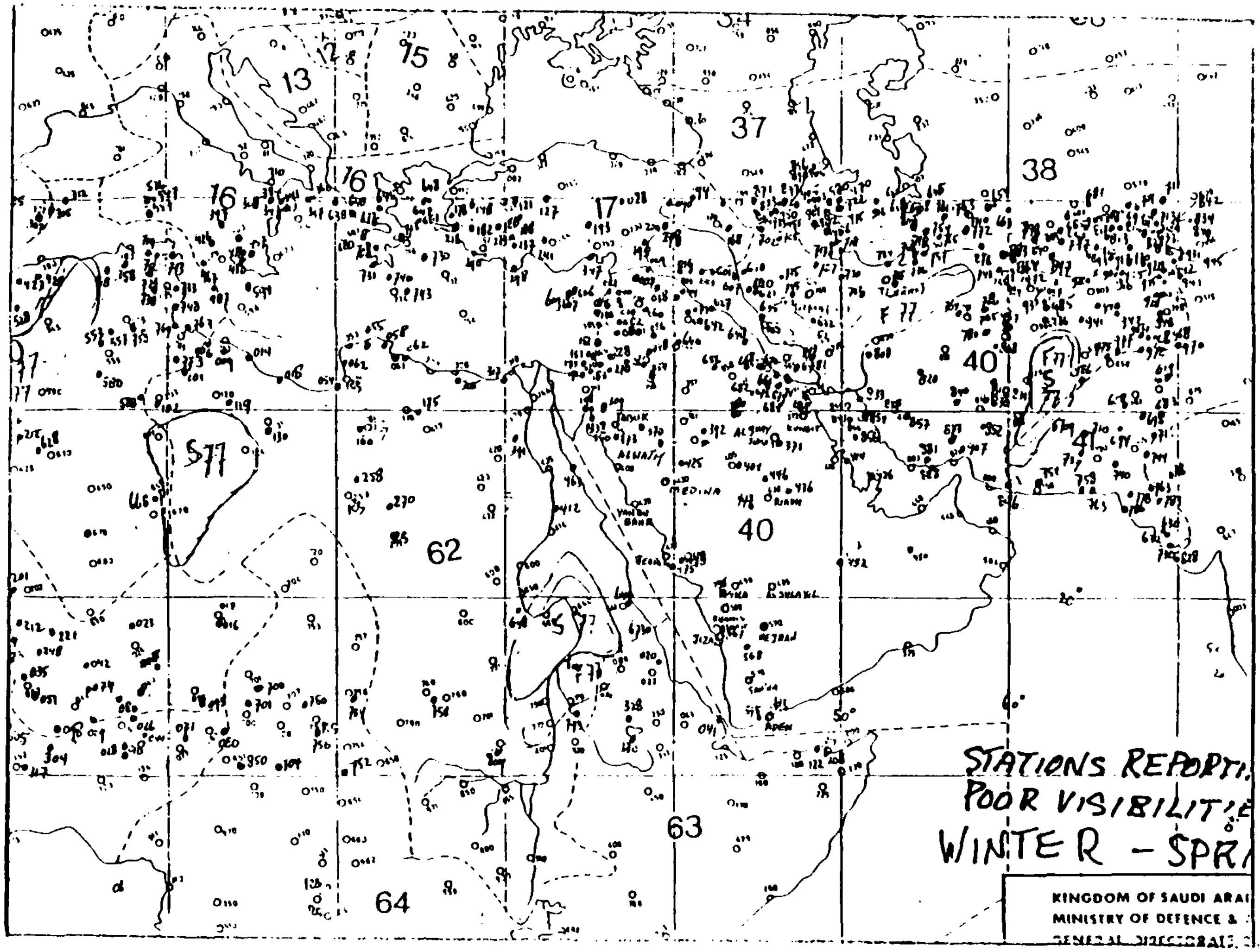

Figure 3. Three-year Calendar of days with poor visibility for station 40928

BLOCK STATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
40 928 January					O	O					+				O				O	O			O +	O +	O +	+	+	+	O +		
February		O							O																		O				
March										+	O			+	+	O +	O +		O			+				O	+	O			+
April			+												O		+	+	+		+			O				+			
May												+	O												+			O	O	O	O
June																															
July																						O									
August																															
September																															
October																															
November							O	O	O								O			O											
December									O	O									O						O	O					

O 1977
+ 1978
Δ 1979

To be completed.

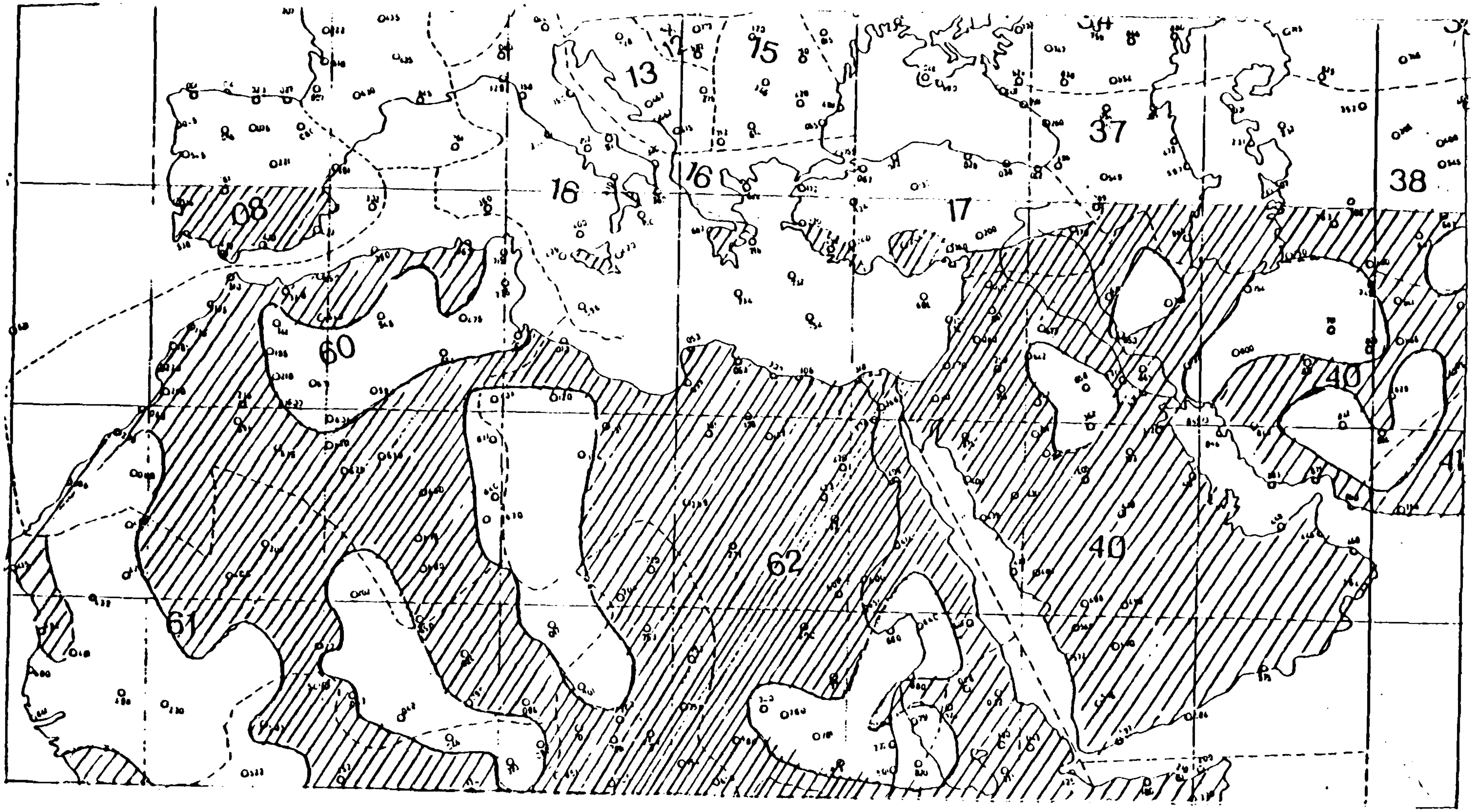

Figure 4 Map showing the distribution of poor visibilities for 1977.

Shaded areas: poor visibilities reported during all seasons. Blank areas: no reports of poor visibility during at leas one season.

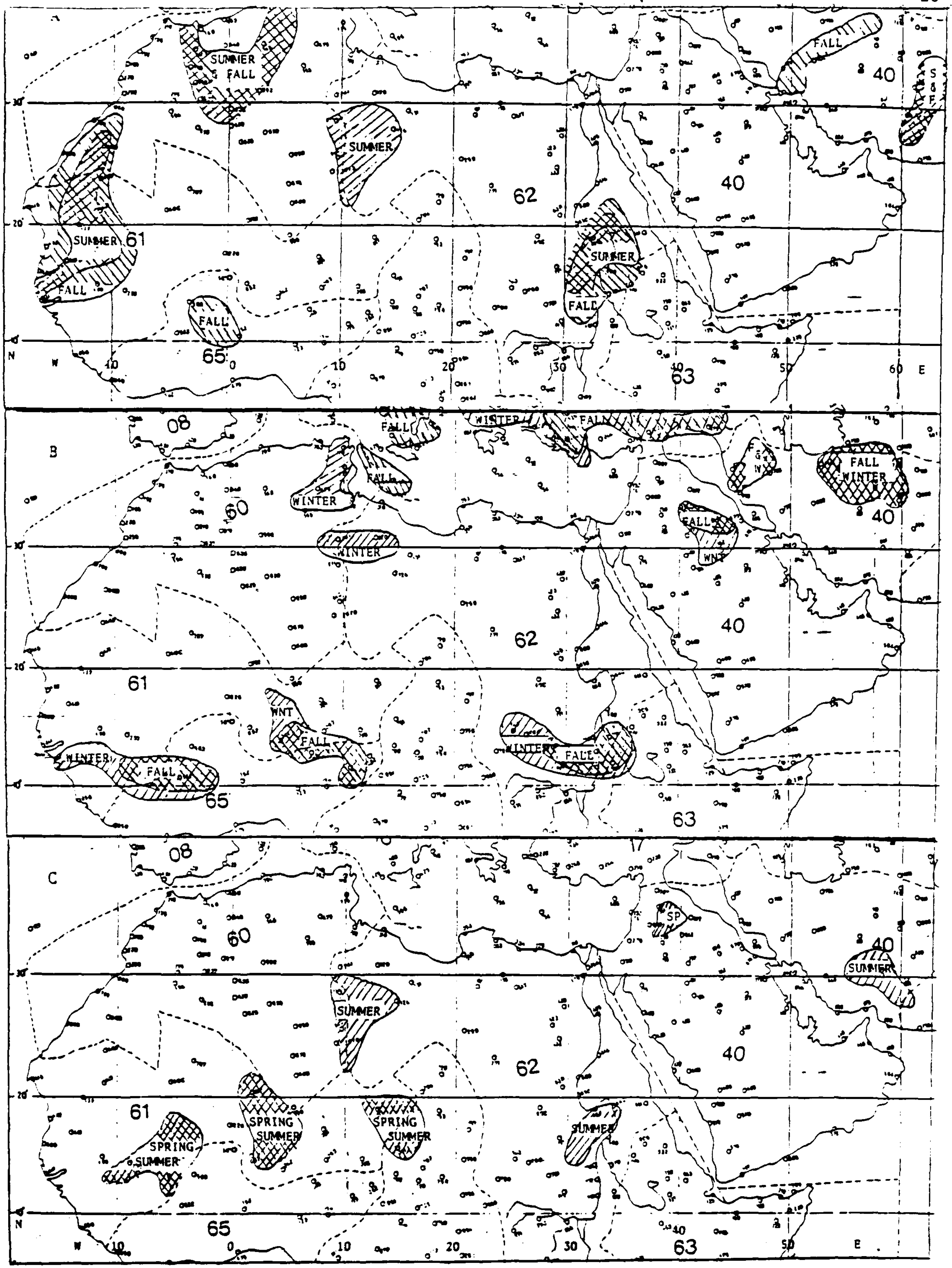

Fig 5 Areas in which poor visibility was reported during limited periods in 1977
A: late summer and early fall, B: late fall and winter, C: spring and early summer.